



Mid-IR Quantum-Well Devices

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Abstract:

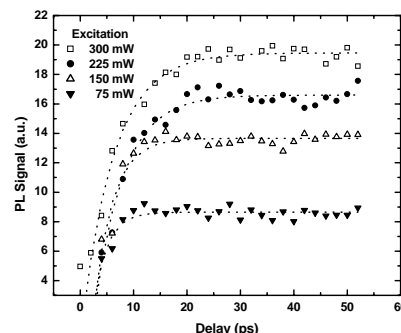
Mid-infrared (IR) semiconductor lasers are well suited for a variety of USAF applications including optical communications, IR counter-measures and laser radar. Antimony-based semiconductors are a good choice for IR laser devices because of their flexibility to be grown to take advantage of the atmospheric transmission window from 3-5 μm . While the size of such devices is attractive for aircraft applications, output power at elevated temperatures (i.e., $>77\text{ K}$) has been marginal. Mid-IR semiconductor laser performance is optimized in this work with respect to such critical parameters as increased output power and operating temperature through an iterative design, fabrication, testing, and optimization process.

Research Methods:

The specific technologies worked include: (1) extension of "hot-electron" spectroscopy to the mid-IR for the first time to experimentally measure the semiconductor band-structures of the epitaxial super-lattices designed for mid-IR laser devices; (2) reconciliation of hot-electron measurements with theoretical band-structure models to gain insight into the radiative and nonradiative recombination processes occurring; (3) quantification of both radiative and nonradiative processes for these structures through sub-picosecond spectroscopy; and (4) optimization of epitaxial growth of these super-lattices to improve device electrical and optical performance. Work to date has focused on carrier recombination and carrier relaxation, which have a significant effect on the performance mid-IR semiconductor devices. Time-resolved photoluminescence (TRPL) has been used to study samples grown by molecular beam epitaxy at MIT Lincoln Laboratory or the Air Force Research Laboratory at Kirtland AFB NM.

Results

In these experiments, relaxation rates were observed to decrease with increasing carrier density, which we attribute to hot-phonon effects as initial carrier densities were calculated to be on the order of 10^{19} cm^{-3} . Relaxation rates also decreased with decreasing QW width as expected, indicating reduced intersubband scattering as compared to intrasubband scattering. The temporal evolution of carrier temperature was also determined by full-spectral TRPL. These results also indicate hot-phonon effects and Auger recombination are significant in these samples.



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Funding Sources:

Dayton Area Graduate Studies Institute,
 project SN-AFIT-00-05, \$400K over
 three years
 Air Force Office of Scientific Research,

Publications:

"Time-resolved photoluminescence spectra of mid-infrared quantum-well lasers," S.M. Gorski, M.A. Marciniak, R.L. Hengehold, D.E. Weeks, and G.W. Turner, *Solid State and Diode Laser Technology Review 2002 Technical Digest*, (Directed Energy Professional Society, 2002), p. MIR7.